REMARKS

The present claims relate to a method for forming a wiring, methods for manufacturing a semiconductor device, a copper alloy for wiring, and a semiconductor device.

Amendment summary

Upon entry of this Amendment, claims 7-19, 21-25 will be pending. Claims 7-16 have been withdrawn, pursuant to a previous Restriction Requirement.

Claims 17-19 are amended to recite the process by which the products of those claims are prepared, and removing Ag from the list of compounds therein. Support for these amendments is found, e.g., on page 10, lines 5-10; page 40, line 26; page 25, lines 9-11, page 43, lines 6-9; and in Figure 16 of the present specification.

Claims 21 and 22 are amended, removing Ag from the list of compounds therein.

No new matter is added by this Amendment, and Applicants respectfully submit that entry of this Amendment is proper.

Status of the claims

Claims 17, 19, 21, 23, 24, and 25 stand rejected under 35 U.S.C. § 103(a) as allegedly being unpatentable over Andricacos et al. (EP 0751567) (hereinafter "Andricacos") in view of Nakasaki et al. (JP 02-165632) (hereinafter "Nakasaki"). In addition, claim 18 stands rejected under 35 U.S.C. § 103(a) as allegedly being unpatentable over Andricacos in view of Lee (U.S. Patent No. 5,552,341). Finally, Claim 22 stands rejected under 35 U.S.C. § 103(a) as allegedly being unpatentable over Andricacos in view of Nakasaki and Lee.

Response to claim rejections

The present claims relate to a copper alloy for wiring in which the barrier metal at the interface between the barrier metal film and the polycrystalline copper alloy has not been oxidized. In addition, the copper alloy for wiring is formed by a manufacturing method comprising the steps of: forming a polycrystalline Cu film; forming, on the polycrystalline Cu film, a layer made of an additional element to be added into the polycrystalline Cu film; diffusing the additional element from the additional element layer into the polycrystalline Cu film via crystal grain boundaries to form a polycrystalline copper alloy; and simultaneously therewith performing gettering of oxygen in the polycrystalline Cu film into the additional element layer.

As a result of the process recited in the claims, no oxidation of the barrier metal film occurs, as shown in Figs. 16 and 17 of the present specification. This differs from the normal process, in which oxygen both on the surface of the Cu layer and within the Cu layer diffuses during a heat treatment, leading to an oxidized barrier metal film. The copper alloy for wiring according to the present invention suppresses the oxidation of the barrier metal film, resulting in improved reliability of the copper wiring.

Applicants respectfully submit that the presently claimed invention is neither anticipated by nor rendered obvious by the cited prior art because none of the cited prior art discloses a copper alloy for wiring in which the barrier metal at the interface between the barrier metal film and the polycrystalline copper alloy has not been oxidized. Specifically, Applicants respectfully submit that none of the cited references discloses the presently recited copper alloy made by the presently recited process.

Additionally, Applicants respectfully submit that the present invention provides for the production of wiring with a lower specific resistance than conventional wiring. Since the presently recited additional element is added via the grain boundaries after growth of Cu grains, (in comparison to a normal alloy forming method such as segregating impurities on the grain boundaries by a heat treatment after forming a solid solution of alloy) the concentration of the additional element in the grains can be lowered. As a result, low-resistance wiring can be realized by the present invention.

With respect to the rejection of claims 18 and 20, Applicants respectfully submit that Lee is different from the present invention in the feature and object, as illustrated by the following table:

	Main wiring material	Barrier metal	Segregation location of additional element	Object
Present invention	Cu	Ta	Grain boundaries of the main wiring material	Suppression of grain boundary diffusion of Cu, suppression of barrier oxidation
Lee	Al	Ti	Grain boundaries of the barrier metal layer	Suppression of external diffusion of Al

The description concerning the grain boundary segregation of oxides in Lee relates to grain boundaries of the barrier metal film, and an effect thereof is to suppress the Aluminum, which is the main element of the wiring material, from being diffused to the outside (silicon substrate) through the barrier metal film and causing junction leakage. On the other hand, the present invention relates to grain boundaries of the main wiring material, and aims to suppress grain boundary diffusion of the main wiring material itself and to improve wiring reliability (i.e., improvement in electromigration resistance and improvement in stress migration resistance) by

an oxidation suppressing effect of the barrier metal film. Accordingly, Applicants respectfully submit that Lee, which discloses a different product which functions differently from the present invention, does not cure the deficiencies in Andricacos.

Conclusion

In view of the above, reconsideration and allowance of this application are now believed to be in order, and such actions are hereby solicited. If any points remain in issue which the Examiner feels may be best resolved through a personal or telephone interview, the Examiner is kindly requested to contact the undersigned at the telephone number listed below.

The USPTO is directed and authorized to charge all required fees, except for the Issue Fee and the Publication Fee, to Deposit Account No. 19-4880. Please also credit any overpayments to said Deposit Account.

Respectfully submitted,

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